

The Genus *Rhodiola* (*Crassulaceae*) in the Kunlun Mountains[†]

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The Chinese Academy of Sciences carried out a comprehensive scientific research in the Kunlun Mountains over a three year period beginning in 1987, and a considerable number of specimens of *Rhodiola* were collected by the third author, Wu, and his collaborators. The first author, Ohba, participated in the research in 1988, and observed the living plants, their habitat, ecology, and the variations within and among populations. This study is based principally on specimens collected by the authors and also numerous specimens deposited in A, BM, E, K, KUN, KYO, LE, MO, PE and TI.

As the results of our studies *Rhodiola* is the most diversified genus in the *Crassulaceae* and is represented by 10 species. This is the first taxonomic treatment of *Rhodiola* in the Kunlun Mountains. The species belong to the only two of four subgenera, the *Rhodiola* (9 species) and the *Crassipedes* (1 species). Among these four species, *Rhodiola kunlunica*, *R. feiyongii*, *R. fushuhsiae*, and *R. saxicola* are described here as new species.

Key words: Description of new species, flora, Kunlun Mountains, *Rhodiola*, taxonomy.

Comprehensive scientific research by the Chinese Academy of Sciences in the Kunlun Mountains over a three year period beginning in 1987 resulted in a considerable number of specimens of the Crassulaceous collected by the third author, Wu, and his collaborators. The first author, Ohba, participated in the research in 1988, and observed living plants, their habitat, ecology, and also variation within and among populations.

During the research period, Wu, his collaborators and Ohba intensively collected specimens of the genus *Rhodiola* (*Crassulaceae*) from various localities in the Kunlun Mountains. In this report, some additional collections from the

Karakoram Mountains are included.

Although the genus is distributed throughout the Northern Hemisphere, they are concentrated in the regions located at the southeast margins of the Central Asiatic highland covering Tibet, Qinghai, SW China (Yunnan and Sichuan), and especially in the higher elevations of the Karakoram, Himalaya, Hengduan and Tanghla Mountains. Although *Rhodiola* is estimated to be diverse in the Kunlun Mountains, no information on the genus in the Kunlun region(the Kunlun Mountains and the adjacent regions) was given in previous papers of *Rhodiola* (Ohba 1980–82, 1987, 1989).

This study is based principally on specimens

collected by the authors, and also on numerous specimens deposited in the following herbaria: A, BM, E, K, KUN, KYO, LE, MO, PE, and TI. Our specimens are deposited at KUN and TI, with incomplete sets of duplicates at MO and other institutions. Information on habitat, color of the living materials, and population and local densities are based on our field observations. Flowers were dissected under a binocular microscope after softening. Sketches were made using a camera lucida.

In 1983 C. Y. Yang published a key to all the species of *Rhodiola* known from Xinjiang (Yang 1983) in which he recognized 11 species in *Rhodiola*. Yan-fu Zhang published the *Crassulaceae* of Xinjiang in 'Flora Xinjiangensis,' volume 2(2), in which he reported 14 species of *Rhodiola* (Mao 1995). The southeastern portion of the Kunlun Mountains extends into Tibet.

In our studies in the Kunlun Mountains, *Rhodiola* is the most diversified genus in the *Crassulaceae* and is represented by 10 species. This is the first taxonomic treatment of *Rhodiola* in the Kunlun Mountains.

Results and Discussions

The differences between the 10 species in the Kunlun Mountains and the ones they most closely resemble are shown in the following key. Remarkable features are noted under the entry for each species. The term 'flowering stem' used in this paper is morphologically a lateral branch with flowers arising from the axil of a scale-like (rarely foliage) leaf on the apical portion of the rhizome.

According to Ohba (1979-81) these species belong to only two of four subgenera, *Rhodiola* (sections *Rhodiola* and *Chamaerhodiola*) and *Crassipedes*. *Rhodiola semenovii* of subgenus *Clementsia* occurs in Central Asia. The species of subgenus *Primuloides* and also section *Prainia* of subgenus *Rhodiola* are limited to only the southern part of the Tibetan Plateau. The species of section *Pseudorhodiola* of subgenus

Rhodiola occur in several isolated localities on the eastern margin of the Hengduan Mountains.

Of the species of *Rhodiola* in the Kunlun region, subgenus *Crassipedes* is represented by *R. kunlunica* only. Section *Rhodiola* includes *R. heterodonta*, *R. litwinowii*, *R. feiyongii*, *R. fushuhsiae*, *R. tangutica*, and *R. saxicola*, and subgenus *Chamaerhodiola* comprises *R. tibetica*, *R. quadrifida*, and *R. kaschgarica*.

Rhodiola heterodonta and allied species, *R. imbricata*, *R. litwinowii*, *R. feiyongii*, and *R. lobulata*, consist of a species complex in NW Himalaya ranging from west of C Nepal to Pamir. *Rhodiola pamiroalaica* approaches this species complex. The occurrence of three of five species in the complex in the Kunlun region highlights the strong relationship of the Kunlun and NW Himalaya *Rhodiola* floras. In contrast, species ranging from the eastern Himalaya to the Hengduan Mountains, *Rhodiola crenulata*, *R. bupleuroides* and allies, *R. himalensis*, *R. wallichiana*, *R. sinuata*, and allies belonging to sections *Rhodiola* and *Chamerhodiola* and the *Crassipedes* are completely absent in the Kunlun Mountains. The northern border of the region with the most species is located in southern Qinghai Province, including Yushu.

Species ranging from central to eastern China, such as *Rhodiola kirilowii* (sect. *Rhodiola*) and *R. dumulosa* (sect. *Crassipedes*) are absent in the Kunlun Mountains, and their western border is located also in Qinghai Province.

Rhodiola tangutica shows the floristic relationship to Tangute, now Gansu and Qinghai Provinces. The species is abundant in periglacial habitats in the eastern part of the Kunlun and Altun Mountains. *Rhodiola fushuhsiae* is unique in having a tender procumbent flowering stem, while all other species have erect or bent, rather stout flowering stems. A remarkable feature of sect. *Chamaerhodiola*, here represented by *R. tibetica*, *R. kaschgarica*, and *R. quadrifida*, is that flowering stems persist for one or two years after death, although the plants are essentially

annual except in sect. *Chamaerhodiola*.

Species of sect. *Chamaerhodiola* occur also in habitats similar to those of *R. tangutica*, but more diverse. *Rhodiola tibetica* is fundamentally a NW Himalayan element with some extensions to the eastern part of the Himalayan region. *Rhodiola kaschgarica*, endemic to the Kunlun Mountains, indicates the uniqueness of the flora. The Eastern Himalayan elements of *Chamaerhodiola*, *R. fastigiata*, *R. nobilis*, and *R. himalensis*, are outside the Kunlun Mountains.

Most species in the Kunlun Mountains are invaders of gravelly or scree slopes and on rock surfaces and in crevices, however *Rhodiola fushuhsiae* appears to be terrestrial, growing on the floor of light forests along streams.

In conclusion, the *Rhodiola* flora of the Kunlun region is completely different from the Eastern Himalaya and the Hengduan Mountains and share no common species between them. The affinity of the flora to the NW Himalaya is shown by the presence of the shared species, *R. heterodonta*, and the richness of species in the *R. heterodonta* complex.

The species of *Rhodiola* may be more drought tolerant than other species preferring moist habitats. The environment, however, particularly the low levels of precipitation, blocks even the extension of species of *Rhodiola*, and is main reason for the lower species diversity in the Kunlun Mountains and also the adjacent regions.

Rhodiola L.

H. Ohba in J. Fac. Sci. Univ. Tokyo, sect. III, **12**: 139–198 (1978) [*Rhodiola* in 182–190]; **33**: 337–405 (1980); **13**: 65–199 (1981); **12**: 121–174 (1982); in Eggli, Ill. Handb. Succ. *Crassulaceae*, 210–227 (2003). S. H. Fu in Fl. Reipubl. Popularis Sin. **34**(1): 192 (1984). K. T. (J.) Fu & H. Ohba in Z. Y. Wu & Raven, Fl. China **8**: 251–268 (2001).

Key to the species

1a. Hermaphrodite [subgen. *Crassipedes*]; leaves linear-oblanceolate or oblanceolate, apex

- obtuse; calyx lobes linear to linear-subulate, 1.5–2.2 mm long; styles conspicuously spreading in fruit 1. *R. kunlunica*
- 1b. Dioecious or gynodioecious with bisexual and pistillate flowers [subgen. *Rhodiola*] 2
- 2a. Flowering stems single or few; persistent old flowering stems absent or few [sect. *Rhodiola*] 3
- 3a. Inflorescences of staminate flowers extremely dense, with more than 40 flowers 4
- 4a. Flowers short petiolate; leaves narrowly elliptic or lanceolate or rarely ovate or oblong, base rounded or cuneate, apex acute or obtusely acute 2. *R. litwinowii*
- 4b. Flowers sessile; leaves widely ovate, obovate, pentagonal or narrowly lanceolate, but rarely triangular 5
- 5a. Leaves widely ovate, obovate, pentagonal, but rarely triangular, base truncate or shallowly auriculate to cordate, apical part triangular with acuminate apex 3. *R. heterodonta*
- 5b. Leaves narrowly lanceolate, base rounded, apical part obtuse with acute apex
..... 4. *R. feiyongii*
- 3b. Inflorescences of staminate flowers loose, with less than 20 flowers 6
- 6a. Dioecious; petals of pistillate flowers oblong-lanceolate, 4 mm long; flowering stems ascending to erect, more or less cespitose
..... 5. *R. tangutica*
- 6b. Gynodioecious 7
- 7a. Petals of bisexual flowers without conspicuous apical hooked beak, lamina narrowly to moderately oblong or oblong-spatulate, 2.4–2.8 mm long
..... 6. *R. fushuhsiae*
- 7b. Petals of bisexual flowers with conspicuous apical hooked beak, lamina linear ca. 3.7 mm long 7. *R. saxicola*
- 2a. Flowering stems many, fastigiate; dead flowering stems persistent and often thickening [sect. *Chamaerhodiola*] 8
- 8a. Leaves (1.6–)2–4 mm wide, narrowly obovate to narrowly oblanceolate to oblanceolate or

narrowly ovate; flowering stems 7–15 cm long, 1.5–2 mm thick at flowering
 8. *R. tibetica*

8b. Leaves 0.6–1.5 mm wide, linear to very narrowly oblong to linear-elliptic; flowering stems 1–10 cm long, ca. 0.7–1 mm thick 9

9a. Leaves oblong or linear-lanceolate, 1–2 mm wide; petals yellow, oblong-lanceolate, 3–4 mm long; follicles ca. 3 mm long
 9. *R. kaschgarica*

9b. Leaves linear to linear-elliptic, 0.6–1(–1.2) mm wide; petals red or yellow, oblong-ovate or narrowly oblong-ovate, 2.5–3(–3.5) mm long; follicles 6–7 mm long
 10. *R. quadrifida*

Taxonomic treatment

Within the treatment, the names of the collectors are abbreviated: WOWF, the first W stands for S. G. Wu, O for H. Ohba, the second W for Y. H. Wu, and F for the late Y. Fei. Synonyms, which are not cited here are listed in Ohba (1980–82).

Subgen. *Crassipedes*

1. *Rhodiola kunlunica* H. Ohba, S. Akiyama & S. K. Wu, sp. nov. [Figs. 1 & 2]

Type: CHINA. Xinjiang. Qira Xian: Nuer, elev. 3850 m. On exposed rocky places. S. G. Wu, H. Ohba, Y. H. Wu & Y. Fei 1977. 2 July 1989 (KUN-holo; TI-iso).

Ex affinitate *Rhodiola algida* (Ledeb.) Fisch. & C. A. Mey. stylis in fructu conspicue patentibus et foliis linearis vel normali-oblanceolatis apice obtusis diagnoscenda.

Cespitose perennial herb with obconical rhizomes. Rhizomes often branched, with numerous flowering stems, apex with narrowly ovoid bud 8–11 × 4–5 mm, apex acute. Scale-like leaves widely ovate, 4–7 × 3–6 mm, apex acute. Flowering stems annual, 3–8 in number, persistent usually one year after death, 12–20 cm long, base 1.5–2 mm wide, pale green. Leaves alternate, dispersed, linear-oblanceolate to oblanceolate, 12–16 × 3–5 mm, apex rounded

to rounded-apiculate, base rounded or truncate, margins entire, both surface glabrous.

Inflorescences umbellate cyme, with 10–15 flowers, 1.3–1.7 cm wide, usually without bracts; pedicels 3–5 mm long but often 6–8 mm long in fruit. Flowers hermaphroditic. Calyx tube conical, often reddish, tapering to pedicel, 1.7–2.2 mm long; lobes linear to linear-subulate, 1.5–2.2 × 0.5–0.8 mm, slightly shorter than tube, apex obtuse, erect. Petals cream-yellow tinged with red apically, narrowly oblong to oblong or oblong-lanceolate, 4–5.2 × 1.3–1.5 mm, apex obtuse, upper half spreading at flowering, lower half erect. Stamens slightly shorter than petals, 3.7–4.1 mm long, erect, oppositipetalous ones almost free from petals; filaments pink; anthers dull yellow, ca 0.8 mm long. Nectar scales linear, ca. 1.7 mm long, apex emarginate, deep purplish red. Pistils 4.5–5.6 mm long, lower part embedded in calyx tube, free part 2.3–2.6 mm long; styles short tapering from ovary, erect with apical stigma; ovaries cylindrical, pale pink; ovules 4–8 in each follicle. Follicles 6–7.2 mm long, apical suberect or spreading.

Specimens examined: XINJIANG. Qira Xian: Nuryamei, 4200 m. On meadow by glacier. Fls. yellow. 27 June 1988. WOWF2478 (KUN, TI). Yecheng Xian: Qipan village, 2900 m. Among stone crack in a valley. 17 July 1989. WWF4712 (KUN, TI).

Subgen. *Rhodiola*

Sect. *Rhodiola*

2. *Rhodiola litwinowii* Boriss. in Fl. URSS **9**: 43, 478 (1939). [Fig. 3]

Type: Central Asia. Andizhan Distr. Litvinov s.n. (LE).

C. Y. Yang in Clav. Pl. Xinjing. **2**: 465 (1983). Fu in Fl. Reipubl. Popularis Sin. **34**(1): 192 (1984); in Fl. Xizang. **2**: 421 (1985). Zhang in Mao, Fl. Xinjiang. **2**(2): 244 (1995). K. T. Fu & H. Ohba in Z. Y. Wu & P. Raven, Fl. China **8**: 259 (2001).

Rhodiola recticaules auct. non Boriss. [in Fl. URSS **9**: 478 (1938)]; C. Y. Yang in Clav. Pl. Xinjing. **2**: 458 (1983). Fu in Fl. Reipubl. Popularis Sin. **34**(1): 192 (1984); in Fl. Xizang **2**:



Fig. 1. *Rhodiola kunlunica* H. Ohba, S. Akiyama & S. K. Wu (Xinjiang, Qira Xian, Nuer, 3850 m, WOWF 1977, 2 July 1988, TI, isotype).

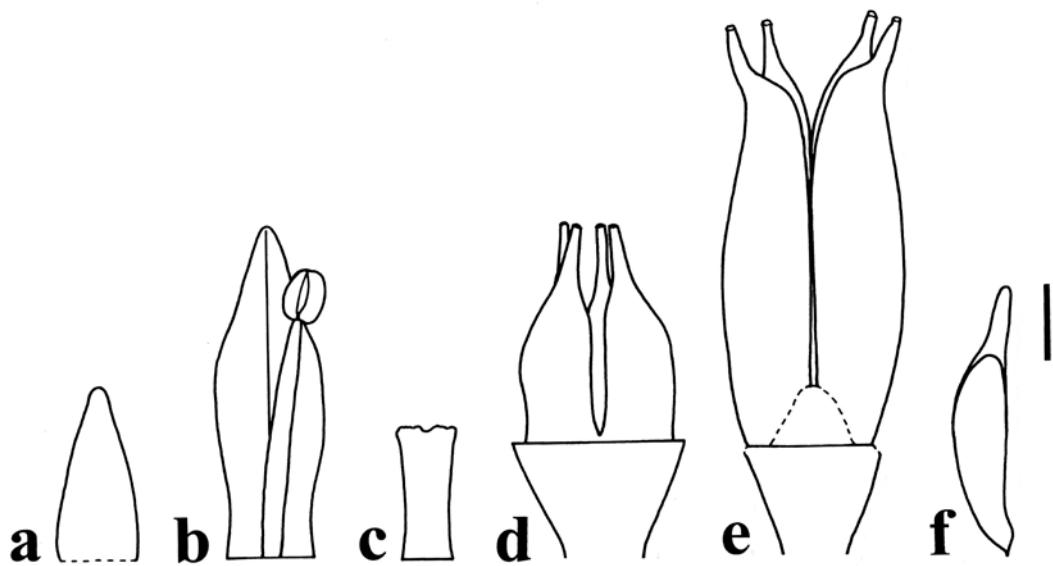


Fig. 2. *Rhodiola kunlunica* H. Ohba, S. Akiyama & S. K. Wu (WOWF 1977, TI, isotype). a. Calyx lobe. b. Petal with a stamen. c. Nectary. d. Ovaries at flowering (an ovary is removed). e. Ovaries in young fruit (an ovary is removed). f. Seed. Bar indicates 1 mm.

421 (1985). Zhang in Mao, Fl. Xinjiang. 2(2): 244 (1995). K. T. Fu & H. Ohba in Z. Y. Wu & P. Raven, Fl. China 8: 258 (2001), pro parte. Type: Central Asia. Pamir. Korshinsky 2540 (LE).

Rhodiola pamiroalaica auct. non Boriss. [in Fl. URSS 9: 40, 477 (1939)]: C. Y. Yang in Clav. Pl. Xinjing. 2:458 (1983). Fu in Fl. Reipubl. Popularis Sin. 34(1):192 (1984); in Fl. Xizang. 2: 421 (1985). Zhang in Mao, Fl. Xinjiang. 2(2): 248 (1995). K. T. Fu & H. Ohba in Z. Y. Wu & P. Raven, Fl. China 8: 243 (2001), pro parte.

Specimens examined: XINJIANG. Taxkorgan Xian: Hongqilapu, ca. 4500–4700 m. 12 Aug. 1989. WWF 4895 (KUN, TI).

Borissova (1939) classified *Rhodiola litwinowii* in section *Chamaerhodiola* because of its numerous persistent dead flowering stems, however the type and other authentic specimens identified by her have only a few persistent stems. *Rhodiola litwinowii* approaches *R.*

imbricata described from Kumaon, India. The specimens collected from the Himalaya and the Indian side of the Karakorum Mountains have leaves with entire or few toothed margins, although the situation appears to show a geographical tendency from the rather smooth leaves of the Himalayan and Indian Karakorum plants named *R. imbricata* to the rather conspicuously serrated ones of *R. litwinowii*, no specimen showing an intermediate situation have been seen.

Rhodiola recticaulis described by Borissova (1939) based on Korshinsky 2540 (LE) from Pamir was reported from Xingjiang by several workers. Borissova (1939) also classified *R. recticaulis*, with its numerous dead flowering stems and dioecious nature, in section *Chamaerhodiola*. Plants attributed to *R. recticaulis* might be *R. litwinowii* or *R. imbricata*. *Rhodiola recticaulis* are easily distinguishable from *Rhodiola litwinowii* and *R. imbricata* in having magnificent rhizomes with numerous



Fig. 3. *Rhodiola litwinowii* Boriss. (Xinjiang, Taxkorgan Xian, Hongqilapu, 45–4700 m, WWF 4895, 12 Aug. 1989, TI).

branches and thick persistent dead flowering stems and ovate to oblong-ovate leaves 8–10 × 2–3 cm.

Rhodiola pamiroalaica Boriss. was also described from Central Asia based on Korshinsky 2535 and 2537 (LE). The Kunlun and Karakorum plants attributed to *R. recticaulis* appear to differ from true *R. pamiroalaica*, and to fall within the range of variation of *R. litwinowii*.

3. ***Rhodiola heterodonta*** (Hook. f. & Thomson) Boriss. in Fl. URSS 9: 32, t. 3, f. 3a (1939). [Fig. 4]

Type: Kashmir. Thomson s.n. (K).

C. Y. Yang in Clav. Pl. Xinjing. 2: 458 (1983). Fu in Fl. Reipubl. Popularis Sin. 34(1): 192 (1984); in Fl. Xizang. 2: 421 (1985). H. Ohba in J. Fac. Sci. Univ. Tokyo, sect. III, 13: 79 (1981); in Eggli, Ill. Handb. Succ. *Crassulaceae* 216 (2003). Zhang in Mao, Fl. Xinjiang. 2(2): 248 (1995). K. T. Fu & H. Ohba in Z. Y. Wu & P. Raven, Fl. China 8: 262 (2001).

Sedum heterodontum Hook. f. & Thomson in J. Linn. Soc. (Bot.) 2: 95 (1858).

Rhodiola viridula Boriss. in Fl. URSS 9: 510 (1939), versim. Type: Jugum Chatkal (Kyrgyzstan, westernmost part), Fluvius Sandalasch. O. Knorring 238a, 15 July 1938 (LE). C. Y. Yang in Clav. Pl. Xinjiang. 3:460 (1983).

Specimens examined: XINJIANG. Taxkorgan Xian: Mintiegai, 4460 m. On gravel slope. Fl. yellow. 15 Aug. 1989. WWF 5000 (KUN, TI).

Rhodiola heterodonta ranges from the Nepal Himalaya westward to Pamir, and in the Kunlun Mountains it occurs only in the westernmost area connected with the Karakorum Mountains. *Rhodiola viridula* described from the Chatkal Mountains, Kyrgyzstan, appears to be a synonym of *R. heterodonta*.

4. ***Rhodiola feiyongii*** H. Ohba, S. Akiyama & S.-K. Wu, sp. nov. [Figs. 5 & 6]

Type: CHINA. Xinjiang. Akto Xian: Qiaarnong, elev. 3900 m. On gravel slope. Fl. yellow. S. G. Wu, Y. H. Wu & Y. Fei 5009, 9

July 1989 (KUN-holo; TI-iso).

Species inter *Rhodiola heterodonta* (Hook. f. & Thomson) S. H. Fu et *R. imbricatam* Edgew. aut *R. litwinowii* Boriss., haec bene differt ab illo foliis angustioribus, in forma lanceolatis vel anguste oblongis, caulis dense depositis, ab his inflorescentia semi- vel prope globosa, floribus multis dense deposita.

Perennial dioecious herb with obconical thick rhizome. Scale-like leaves ovate or widely ovate, 7–15 × 4–10 mm. Flowering stems to 15 cm tall, base 4–5 mm thick, glabrous, pale green but in upper part often reddish. Leaves alternate, lanceolate or narrowly oblong, 0.8–1.2 cm × 2–4 mm, apex acute, base truncate or rounded, margins entire to sparsely serrate, both surfaces glabrous. Inflorescences (♀) a compact cyme, semi- or nearly globose, 2–2.5 cm across; bracts mostly absent; pedicels (including calyx tube) 2–5 (–6) mm long, glabrous, pale green. Flowers (♂) unknown. Flowers (♀) 5-merous, Calyx tube continued to and indistinguishable from pedicel; lobes linear, 1.8–2.1 × 0.5–0.8 mm, apex obtuse, erect. Petals oblanceolate or oblong-oblanceolate, 3.5–4 × 1.1–1.4 mm, apex rounded-apiculate, erect through anthesis. Androecium completely absent. Nectar glands rectangular, ca 0.5 mm long and wide, apex truncate, pale. Gynoecium 4–6 mm long at flowering, slender, tapering to indistinguishable style; stigma ± capitate; ovaries almost free.

Additional specimens examined: XINJIANG. Akto Xian: Qiaarnong, 3800 m. On meadow. 9 July 1989. WWF 4630 (KUN, TI). Taxkorgan Xian: Hongqilapu, 4700 m. On paramos near glacier. 13 Aug. 1989. WWF 4916 (KUN, TI).

This new species is named after late Mr. Fei Yong, a botanist in the Herbarium, Kunming Institute of Botany, Chinese Academy of Sciences, who participated in the Tibetan Plateau Expeditions of the Chinese Academy of Sciences, and prepared a preliminary list of the plants collected in the Kunlun Mountains.

This new species is classified between *Rhodiola heterodonta* and *R. imbricata* or *R. litwinowii*. The specimens examined were all



Fig. 4. *Rhodiola heterodonta* (Hook. f. & Thomson) Boriss. (Xinjiang, Taxkorgan Xian, Mintiegai, 4400 m, WWF 5000, 15 Aug. 1989, TI).

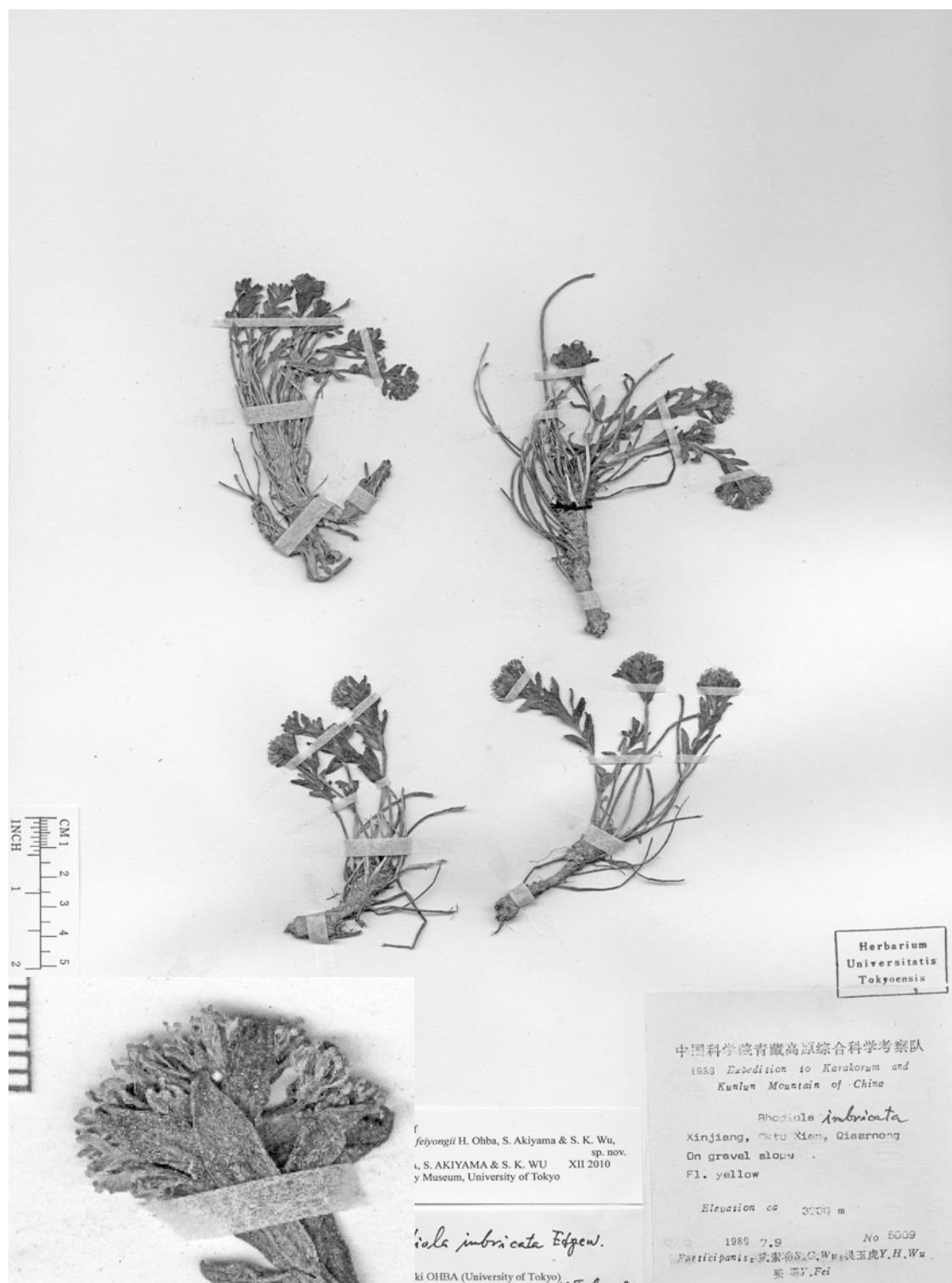


Fig. 5. *Rhodiola seiyongii* H. Ohba, S. Akiyama & S. K. Wu (Xinjiang, Akto Xian: Qiaarnong, 3900 m, WWF 5009, 9 July 1989, TI, isotype).

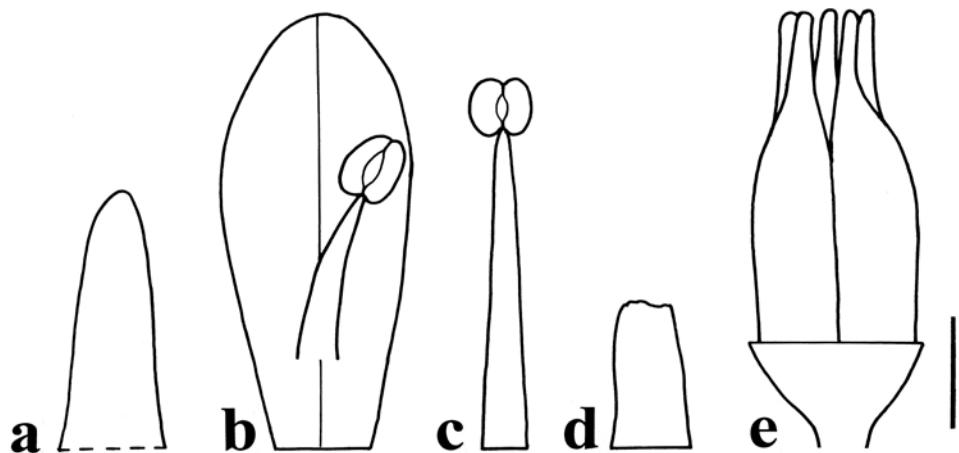


Fig. 6. *Rhodiola feiyongii* H. Ohba, S. Akiyama & S. K. Wu (WWF 5009, 9 July 1989, TI, isotype). a. Calyx lobe. b. Petal with a stamen. c. Aternipetalous stamen. d. Nectary. e. Ovaries at flowering. Bar indicates 1 mm.

pistillate and no staminate individuals were collected. The dissected flower shown in Fig. 6 might be immature, because the stamens are shorter than the petals. All the species of subgenus *Rhodiola* have stamens longer than the petals. Although the flower appears to be bisexual with relatively large pistils (Fig. 6e), is staminate. The ovary has no ovules and is abortive.

Because the characters of *Rhodiola feiyongii* show some intermediacy, it might be an interspecific hybrid between the species mentioned above. For more detailed studies, additional materials are needed.

5. *Rhodiola tangutica* (Maxim.) S. H. Fu in Bull. Bot. Res. Harbin **6**: 158 (1986). [Fig. 7]

Type: CHINA. Regio Tangut (Gansu Prov.). 20 Jul.-1 Aug. 1880. Decliv. N. juga. in Ietung, regio alpina. 10-12000 ft. Przewalski 649 (LE-lecto).

S. H. Fu in Fl. Reipubl. Popularis Sin. **34**(1):192 (1984); in Fl. Xizang. **2**: 421 (1985). K. T. Fu & H. Ohba in Z. Y. Wu & Raven, Fl. China **8**: 260 (2001). H. Ohba in J. Jpn. Bot. **85**:

291 (2010).

Sedum algidum Ledeb. var. *tanguticum* Maxim. in Bull. Acad. Sci. St.-Pétersb. **29**: 126 (1883).

Specimens examined: XINJIANG. Qiemo Xian: Konqibulaker, 4000 m. On steep soil slope among rock. Ovaries reddish. 25 July 1988. WOWF 2093 (KUN, TI). Ruoqiang Xian: N slope of Altum Mountain, 3600 m. On gravel in slope. Fr. red. 29 Aug. 1988. WOWF 2780 (KUN, TI); Aqqikkol, 4380 m. On meadow in sand. 17 Aug. 1988. WOWF 4116 (KUN, TI); E of Aqqikkol, 4600 m. By streams near limestone cane. 17 Aug. 1988. WOWF 2236 (KUN, TI); Hasheklei River, 4300-4800 m. On meadow in gravel. 19 Aug. 1988. WOWF 4157 (KUN, TI); Hongliugou to Mangnai, 2800 m. On rocky banks by stream. Fruit reddish. 4 Aug. 1988. WOWF 2129 (KUN, TI); Lamuqiman, 4320 m. On meadow in sand by water. 18 Aug. 1988. WOWF 4124 (KUN, TI); 125 km from Mangnai, 3650 m. On stony steep slope. 29 Aug. 1988. WOWF 2341 (KUN, TI); Qimantag, 4300 m. On rocky slope. 9 Aug. 1988. WOWF 2170 (KUN, TI); 4400 m. On rocky gentle slope among rocks. 10 Aug. 1988. WOWF 2180 (KUN, TI); 4500 m. On rocky gentle slope among rocks. 10 Aug. 1988. WOWF 2181 (KUN, TI); 4600 m. Among rocks in scree. 10 Aug. 1988. WOWF 2187 (KUN, TI); Qimantag Mt., 4300-4700 m. In rock crack. Fls red to yellow. 9 Aug. 1988. WOWF 3972 (KUN, TI); Whale lake, 4700 m. In flood land. Fru. red. 13 Aug. 1988. WOWF 3069 (KUN, TI); Yaziqian, 4400 m. Near water. 23 Aug.

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Fig. 7. *Rhodiola tangutica* (Lebed.) S. H. Fu (Xinjian. Ruoqiang Xian, Qimantag, 4500 m, WOWF 2180, 10 Aug. 1988, TI).

1988. WOWF 2749 (KUN, TI); A pass between Yaziqian and Aqqikkol Hu, 4450 m. 23 Aug. 1988. WOWF 2283 (KUN, TI). TIBET. Baingoin Xian: Biyun mountain, N of Whale lake, 5000 m. On gentle slopes. 14 Aug. 1988. WOWF 2214(m) (KUN, TI); Kunlun Mountain, NEN of Whale lake, 5000 m. By streams on ground covered slopes. 15 Aug. 1988. WOWF 2234 (KUN, TI). QINGHAI. Golmud Xian: 920 km in highway from Qinghai to Tibet, 4400 m. In slope. Fr. red. 6 Sept. 1988. WOWF 2818 (KUN, TI). TIBET. Baingoin Xian: Biyunshan, near Whale lake. On gravel near glacier. Fls. pink. Fr. red. WOWF 2703 (KUN, TI); NW of Whale lake, 4800 m. Along streams in alpine desert. Young fruit red. 13 Aug. 1988. WOWF 2210 (KUN, TI). REGIO TANGUT. Sine loc. special, Przewalskii 156 (Mai, 1880) (LE—paratype of *S. algidum* var. *tanguticum*); Przewalski 153 (23 June/5 July, 1872) (LE); Terra Tangutorm. Przewalski s.n. (15/27 Aug. 1872) (LE).

Rhodiola tangutica differs from *R. algida* (Ledeb.) Fisch. & C. A. Mey. in its dioecious nature. It grows often gregariously on gentle rocky slopes and is rather common at least in the eastern part of the Kunlun and also the Qimantag Mountains.

6. *Rhodiola fushuhsiae* H. Ohba, S. Akiyama & S. K. Wu, sp. nov. [Figs. 8 & 9]

Type: CHINA. Xinjiang. Pishan Xian: Buqun, elev. 2800 m. On steep soil banks by river. S. G. Wu, H. Ohba, Y. H. Wu & Y. Fei 1835. 17 June 1988 (KUN—holo; TI—iso).

Bene differt ex affinitate *Rhodiola cretinii* (Raym.-Hamet) H. Ohba emodii orientalis aut *R. ludlowii* H. Ohba bhutanicae, ab utroque rhizomatibus multo ramosioribus, ex *Rhodiola cretinii* petalis anguste- vel normale oblongi vel oblongi-spatulatis (non angustissime normali- vel angulari-ellipticis nec linearis-ovovatis) et seminibus 2.1–2.3 (non 1.6–1.9) mm longis, ex *R. ludlowii* inflorescentia 4–7 floribus ornata (nec floriore solitari) et foliis linearibus (nec spatulatis nec oblanceolatis).

Gynodioecious, perennial herb. Rhizome slender, creeping, 1.5–2.2 mm thick, well branched. Scale-like leaves triangular. Flowering stems 2–4 from each branch every year, spreading or ascending, glabrous, smooth, green without red shade. Leaves alternate, with

intervals nearly as long as leaf length, sessile, linear, 0.8–1.4 cm × 0.8–1.3 mm, apex rounded or obtuse, base widely cuneate, entire, both surfaces glabrous. Inflorescences cymes with 4–7 flowers, without bracts; peduncles ca. 3–4.2 mm long, glabrous; pedicels ca. 3 mm long, glabrous.

Calyx obconical, ca. 0.8 mm long; lobes ascending, tip reddish, linear or oblong, 1.2–1.6 × 0.6–0.9 mm, apex rounded, suberect at flowering. Petals inner surface creamy yellow, outer surface reddish, narrowly to moderately oblong or oblong-spatulate, 2.4–2.8 × 0.8–1.2 mm, apex rounded, basally ascending to suberect, upper part spreading. Stamens in hermaphrodite flowers shorter than petals, ca. 2 mm long, oppositipetalous ones connate ca. 1 mm from base; filament creamy white; anthers red, ca. 0.5 mm long. Nectar scales deep purplish red, ca. 1.2 mm long, apex rounded, often reflexed. Pistils 3.5–4.2 mm long, lower part embedded in calyx tube, upper part tapering, slightly bent on dorsal side; styles indistinguishable; stigma red; ovules 6–8 in each locule. Follicles ca. 8 mm long, apical part conspicuously bent on dorsal side. Seeds ca. 2.3 mm long.

The epithet commemorates Dr. Fu Shu Hsia (1906–1986), who contributed greatly to the taxonomy of *Crassulaceae*, particularly *Rhodiola* and its diversity in China.

Additional specimens examined: XINJIANG. Akto Xian: Qiaernong, 3900 m. On meadow. Fl. yellow. 9 July 1988. WOWF 5024 (KUN, TI). Hotan Xian: Taxkax, 3700 m. On slope-grassland. Fruit red. 10 July 1988. WOWF 2563 (KUN, TI). Pishan Xian: Buqiang, 2800 m. On grasslands near water. Fls. red. 17 June 1988. WOWF 3008 (KUN, TI); 3400 m. On grasslands in slope. 19 June 1988. WOWF 3012(f) (KUN, TI); Buqun, 2800 m. On soil steep banks by valley. Petals & sepals erect, reddish outside. 17 June 1988. WOWF 1827(f) (KUN, TI); Buqun, S valley of the interior of Buqun, 2850 m. Sunny soil banks. 18 June 1988. WOWF 1840(f) (KUN, TI); Naoarbati, 2800 m. Grassland in forest on slope. 17 June 1988. WOWF 2414(m) (KUN, TI); Naoabatibusqiong, 3400 m. On grassland. 18 June 1988. WOWF 2433 (KUN, TI); Kaxtax, 3200–3500 m. On grassland in *Sabina* shrubbery. Fls. red

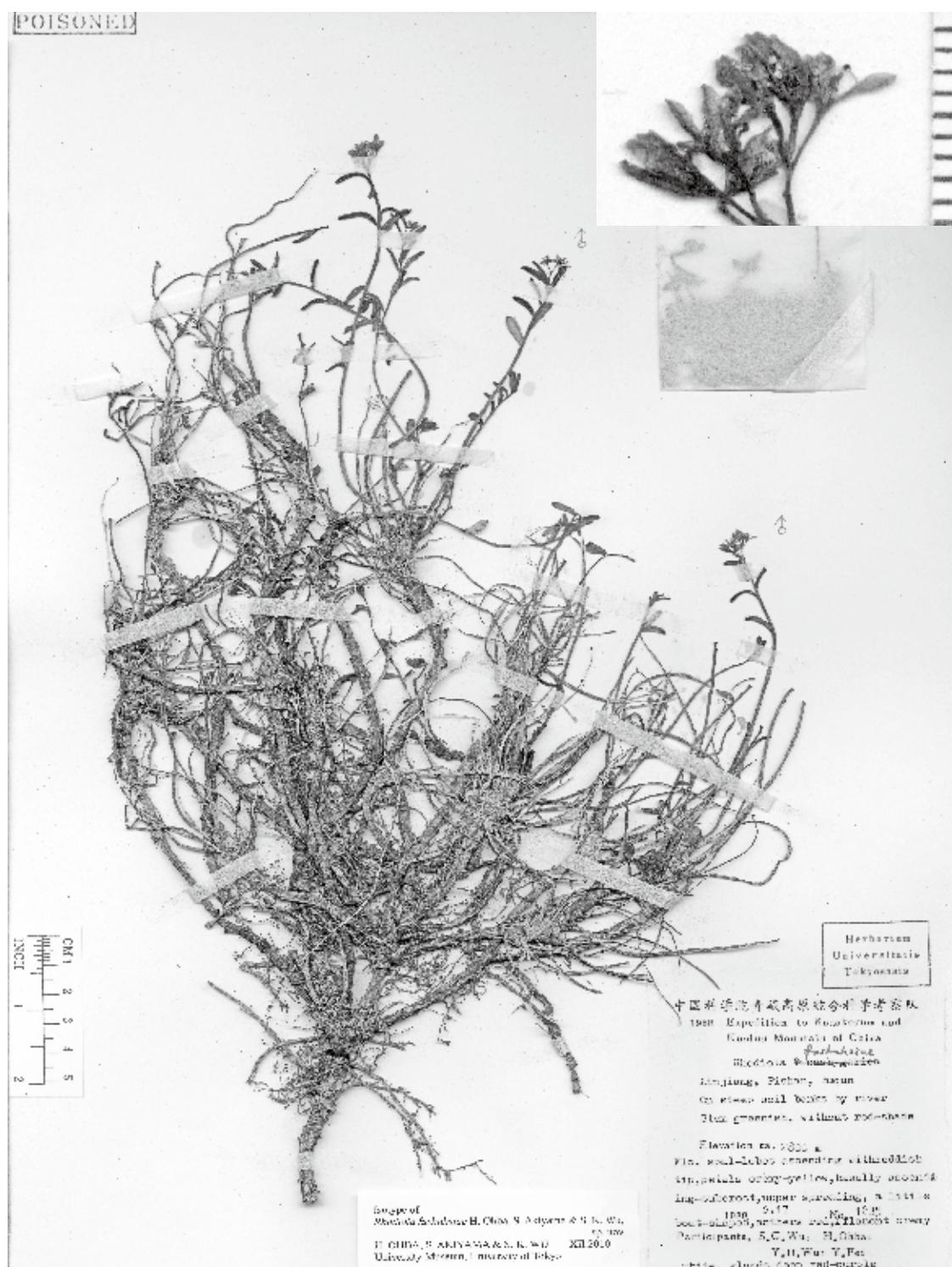


Fig. 8. *Rhodiola fushuhiae* H. Ohba, S. Akiyama & S. K. Wu (Xinjiang, Pishan Xian, Buqun, 2800 m, WWF 1835, 17 June 1989, TI, isotype).

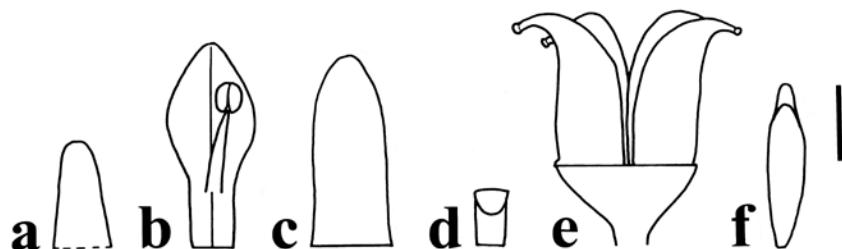


Fig. 9. *Rhodiola fushuhsiae* H. Ohba, S. Akiyama & S. K. Wu (WWF 1835, TI, isotype).

a. Calyx lobe. b. Petal with a stamen (male). c. Petal (female). d. Nectary. e. Ovaries at flowering. f. Seed. Bar indicates 1 mm.

and yellow. 18 June 1988. WOWF 3653 (KUN, TI). Qira Xian: Nuer, 3800 m. On exposed rocky slopes. 1 July 1988. WOWF 1959 (KUN, TI). Yacheng Xian: Qipan village, 3100 m. Among forest. 16 July 1989. WWF 4658(f) (KUN, TI).

Rhodiola fushuhsiae, occurring on gentle soil slopes by streams, is related to *R. cretinii* of East Himalaya and *R. ludlowii*. *Rhodiola cretinii*, which grows on or among rocks and boulders, is distinguished from *R. fushuhsiae* by its gynodioecious nature and oblong or oblong-spatulate petals. *Rhodiola ludlowii* from Tibet differs by having flowering stems with solitary flowers.

7. *Rhodiola saxicola* H. Ohba, S. Akiyama & S. K. Wu, sp. nov. [Figs. 10 & 11]

Type [with bisexual flower]: CHINA. Xinjiang. Qiemo Xian: Kongqibulaker, 4000 m. Grazing land. Fls. red. S. G. Wu, H. Ohba, Y.-H. Wu & Y. Fei 2601. 22 July 1988 (KUN-holo, TI-iso). **Paratype** [with pistillate flower]: Qiemo Xian: Kongqibulaker, 4100 m. Among rocks in small dry river. Ovary reddish. S.-K. [G.] Wu, H. Ohba, Y.-H. Wu & Y. Fei 2076. 22 July 1988 (KUN; TI).

Affinitate *Rhodiola fushuhsiae* H. Ohba, S. Akiyama & S. K. Wu sed haec gynodioecia, petalis linearibus (nec anguste vel moderato

oblongi lanceolatis), ca. 3.7 (nec 2.4–2.8) mm longis, horum apice conspicue uncinati rostrato satis digoscenda

Gynodioecious, perennial herb. Rhizome slender, erect or suberect, 6–10 mm thick, sparsely branched, scale-like leaves triangular. Flowering stems cespitose, usually 6–12 from each branch every year, erect or suberect, glabrous, smooth, green without red shade. Leaves alternate, with intervals nearly as long as 1/2 to 2/3 leaf length, sessile, linear-ob lanceolate or narrowly oblanceolate, 1–1.7 cm × 3.5–5.5 mm, apex rounded, base widely cuneate, entire, both surfaces glabrous. Inflorescences cyme with 4–9 flowers, without bracts; peduncles inconspicuous; pedicels ca. 3 mm long, glabrous.

Calyx obconical, ca. 1.5 mm long; lobes ascending, linear, ca. 1.3 × ca. 0.6 mm (in bisexual flowers) and ca. 2.5 × 0.6 mm (in pistillate flowers), apex rounded, suberect at flowering. Petals deep red, linear, ca. 3.7 × 1 mm (in bisexual flowers) and ca. 25 × 0.6 mm (in pistillate flowers), apex with conspicuous hooked beak, ca. 0.5 mm long (in bisexual flowers), basally ascending to suberect, upper part spreading. Stamens slightly longer than petals, ca. 3 mm long; filament ca. 1.1 mm connate with petal; anthers ca. 0.5 mm long.



Fig. 10. *Rhodiola saxicola* H. Ohba, S. Akiyama & S. K. Wu (Xinjiang. Qiemo Xian: Kongqibulaker, 4000 m, WOWF 2601, 22 July 1988, TI, isotype).

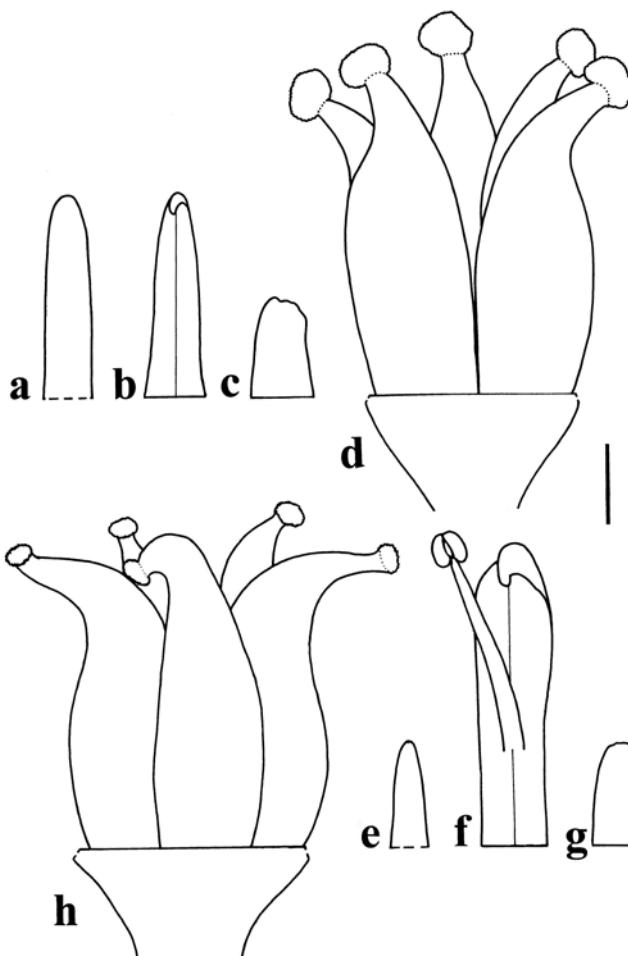


Fig. 11. *Rhodiola saxicola* H. Ohba, S. Akiyama & S. K. Wu (a-d: WOWF 2076, TI, paratype. e-h: WOWF 2601, TI, isotype). a. Calyx lobe. b. Petal. c. Nectary. d. Ovaries at flowering. e. Calyx lobe. f. Petal with a stamen. g. Nectary. h. Ovaries at flowering. Bar indicates 1 mm.

Nectar scales ca. 1.2×0.5 mm (in bisexual flowers), ca. 1.2×0.8 mm (in pistillate flowers), apex rounded or truncate. Pistils lower part embedded in calyx tube, free part 4–4.4 mm (in bisexual flowers) or 4.5–5 mm (in pistillate flowers) long, upper part more or less bent on dorsal side, tapering; styles indistinguishable; stigma red, swollen, capitate; ovules 2–4 (in bisexual flowers) or 8 (in pistillate flowers) in each locule. Follicles and seeds unknown.

Rhodiola saxicola, endemic to Kongqibulaker, Qiemo Xian at 4000 m elevation, is related to

R. fushuhsiae, occurring in areas westward of Qiemo Xian, but clearly distinguished from it by having peculiarly formed petals with a conspicuous apical beak and swollen capitate stigmas.

Sect. *Chamaerhodiola*

8. *Rhodiola tibetica* (Hook. f. & Thoms.) S. H. Fu in Acta Phytotax. Sin. Addit. 1: 121 (1965). [Fig. 12]

Type: Tibet. Thomson s.n. (K).

S. H. Fu in Fl. Reipubl. Popularis Sin.

34(1):192 (1984); in Fl. Xizang. **2**: 421 (1985). H. Ohba in J. Fac. Sci. Univ. Tokyo, sect. III, **13**: 79 (1981). Zhang in Mao, Fl. Xinjiang. **2**(2): 248 (1995). K. T. Fu & H. Ohba in Z. Y. Wu & P. Raven, Fl. China **8**: 258 (2001).

Sedum tibeticum Hook. f. & Thomson in J. Linn. Soc. Bot. **2**: 96 (1858).

Sedum stracheyi Hook. f. & Thomson in J. Linn. Soc. Bot. **2**: 96 (1858).

Specimens examined: XINJIANG. Akto Xian: Wuyitage, 2800 m. Among *Picea* forest. 6 Aug. 1989. WWF 4810 (KUN, TI). Pishan Xian: Habake Daban, 4000 m. On gravel land in a valley. Fruit red. 27 July 1989. WWF 4768 (KUN, TI). Qira Xian: Nuer, 4100 m. On soil among rocks. Pistillate fls. deep red. 27 June 1988. WOWF 1921 (KUN, TI); Petal creamy white with red tip and margin. 27 June 1988. WOWF 1922 (KUN, TI); 3800 m. On exposed ridge. 1 July 1988. WOWF 1958 (KUN, TI). Texkorgan Xian: Kalaqigu, 4400–4500 m. On gravel land. Fruit red. 16 Aug. 1989. WWF 5086 (KUN, TI). Yutian Xian: Pulu, Sanchakou, 3300 m. In crack of stone of groove. Pistillate flowers red. 7 July 1988. WOWF 3796 (KUN, TI).

9. *Rhodiola kaschgarica* Boriss. in Fl. URSS **9**: 39, t. 3. f. 5a, 476 (1939).

Type: CHINA. [Xinjiang] Kaschgar. Divnogorskaya s.n. 11 June 1909 (LE).

C. Y. Yang in Clav. Pl. Xinjing. **2**: 464 (1983). S. H. Fu in Fl. Reipubl. Popularis Sin. **34**(1): 176 (1984); in Fl. Xizang. **2**: 421 (1985). H. Ohba in J. Fac. Sci. Univ. Tokyo, sect. III, **13**: 157 (foot) (1982). Zhang in Mao, Fl. Xinjiang. **2**(2): 248 (1995). K. T. Fu & H. Ohba in Z. Y. Wu & P. Raven, Fl. China **8**: 262 (2001).

Specimens examined: XINJIANG. Qira Xian: Nuer, 3900 m. On debris covered glacier moraine. Fls. staminate and pistillate (in a single population). 30 June 1988. WOWF 1938 (KUN, TI); 4100 m. On gentle soil among rocks. 27 June 1988. WOWF 1929 (KUN, TI); 4100 m. On alpine tundra and meadow. 27 June 1988. WOWF 3022 (KUN, TI). Taxkorgan Xian: Kalaqigu, 4500 m. On gravel land. Fruit red. 16 Aug. 1989. WWF 5088 (KUN, TI). Yutian Xian: Pulu, 3700 m. On river shoal. 26 June 1988. WOWF 3686 (KUN, TI); Volcano, Luker lake, 4760 m. On meadow by lake. Flowers red. 29 June 1988. WOWF 3701

(KUN, TI); Ulugkula lake, 5100 m. On slope of stone. 30 June 1988. WOWF 3721(m) (KUN, TI).

10. *Rhodiola quadrifida* (Pall.) Fisch. & C. A. Mey., Enum. Pl. Nov. **1**: 69 (1841).

Type: RUSSIA, Siberia (BM).

Rhodiola gelida auct. non Schrenk ex Fisch. & C. A. Mey. [Enum. Pl. Nov. Schrenk. lect. **1**: 67 (1841)]: Boriss. in Fl. URSS **9**: 41 (1939). C. Y. Yang in Clav. Pl. Xinjing. **2**: 464 (1983). S. H. Fu in Fl. Reipubl. Popularis Sin. **34**(1): 176 (1984); in Fl. Xizang. **2**: 421 (1985). Zhang in Mao, Fl. Xinjiang. **2**(2): 248 (1995). K. T. Fu & H. Ohba in Z. Y. Wu & P. Raven, Fl. China **8**: 262 (2001).

Rhodiola coccinea auct. non (Royle) Boriss. [Fl. URSS **9**: 41 (1939)]: C. Y. Yang in Clav. Pl. Xinjing. **2**: 462 (1983). S. H. Fu in Fl. Reipubl. Popularis Sin. **34**(1): 192 (1984); in Fl. Xizang. **2**: 421 (1985). H. Ohba in J. Fac. Sci. Univ. Tokyo, sect. III, **13**: 147 (1982). Zhang in Mao, Fl. Xinjiang. **2**(2): 242 (1995). K. T. Fu & H. Ohba in Z. Y. Wu & P. Raven, Fl. China **8**: 256 (2001).

Specimens examined: QINGHAI. Golmud Xian: Xidatan to Wuyunliang, 4600 m. In gravel on slope. Fruit red. 7 Sept. 1988. WOWF 2898 (KUN, TI).

Plants resembling *Rhodiola quadrifida* found in the Kunlun Mountains are here separated into two species, *R. kaschgarica* and *R. quadrifida*. Most collections are of *R. kaschgarica*, with a single collection of *R. quadrifida*. Their distinguishing characters, however, are unclear. Borissova (1939) distinguished *R. kaschgarica* from *R. quadrifida* mainly by the posture and color of old dead flowering stems, the shape of the leaves and the shape and size of the follicles. Ohba (1982) pointed out that the characters distinguishing these species are variable and inappropriate to use as species demarcation. Further studies including materials collected from adjacent areas are much needed.

We wish to express our thanks to Dr. David E. Boufford for his critical reading the manuscript. Our thanks are also due to the

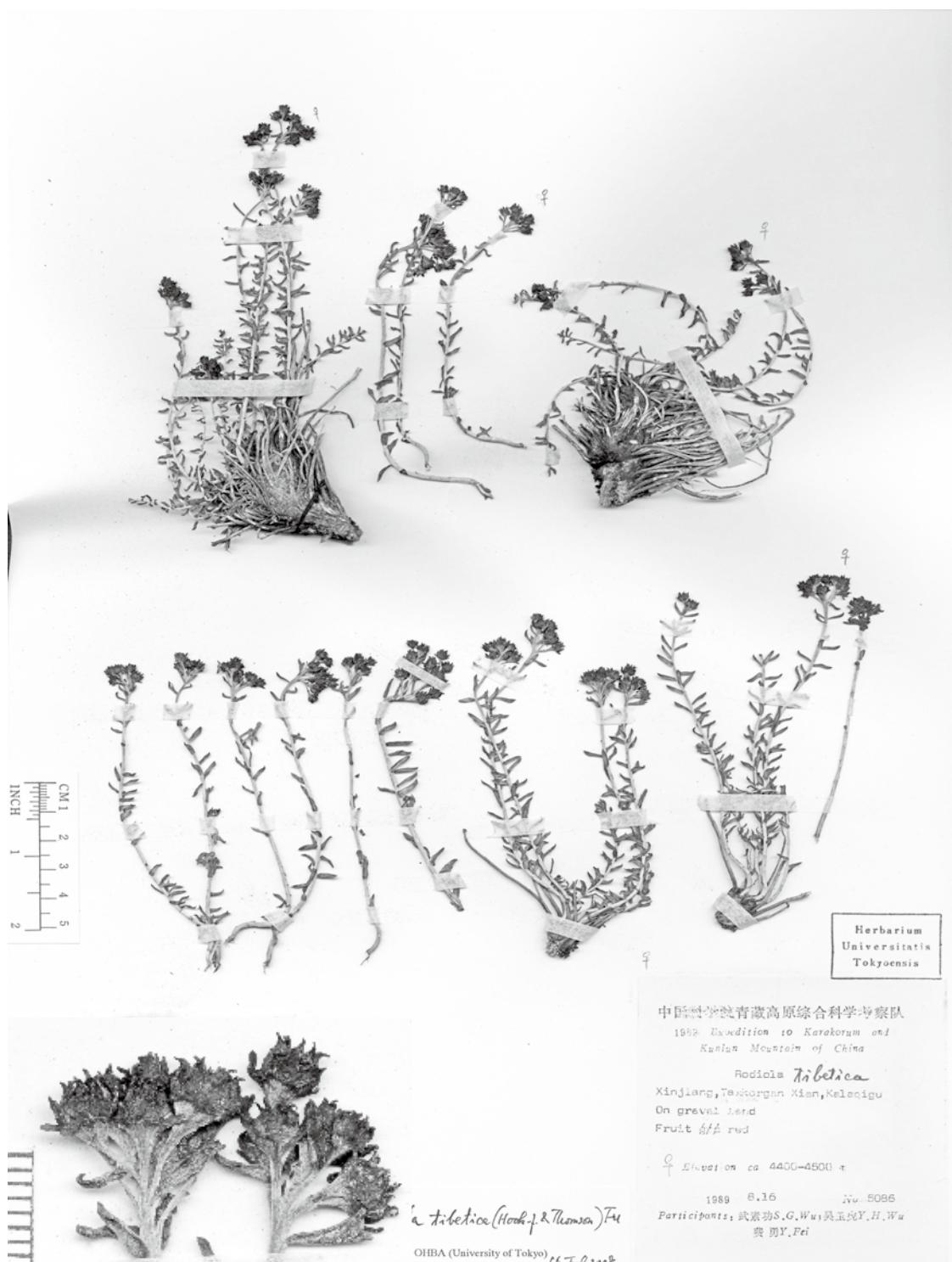


Fig. 12. *Rhodiola tibetica* (Hook. f. & Thoms.) S. H. Fu (Xinjiang, Taxkorgan Xian, Kalaqigu, 4500 m, WWF 5086, 16 Aug. 1989, TI).

directors and curators of the herbaria cited in this paper.

Endnote. [†]Studies of the Flora of the Kunlun and the Karakorum Mountains, Central Asia 5.

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大場秀章^a, 秋山 忍^b, 武 素功^c: 崑崙山脈のイワベンケイ属 (ベンケイソウ科)

中国新疆省とチベットの境に位置し, その西端でカラコルム山脈と接する崑崙山脈で著者らが収集したイワベンケイ属 *Rhodiola* (ベンケイソウ科) 植物を同定した. その結果, 10種が産することが判明した. Ohba(1978年)の分類体系に従い, それらを種名毎に, 正名, タイプ, 異名, 主要文献, 検討した標本の順にまとめて示した. *Crassipedes* 亜属は1種が産する. *Rhodiola kunlunica* は新種として発表するもので, *R. algida* に似るが, 葉形や大きさ, 花などに相違点が認められる.

イワベンケイ亜属イワベンケイ節には6種が認められた. *Rhodiola heterodonta* は西ヒマラヤから崑崙西部に分布することが確かめられた. *Rhodiola litwinowii* は西ヒマラヤに分布する *R. imbricata* に似る. *Rhodiola heterodonta* と西ヒマラヤの *R. imbricata* あるいは上記 *R. litwinowii* の中間的な形態を有する新種, *Rhodiola feiyongii* を記載した. 学名は中国科学院のカラコルム・崑崙調査に加わり採集品仮リストを作成した故

Fei Yong (費 勇) に献呈した. ヒマラヤの *Rhodiola cretinii* やチベットの *Rhodiola ludlowii* に関する新種として, *Rhodiola fushuhsiae* を記載した. 種の形容語はイワベンケイ属の分類に多大な貢献をした故 Fu Shu-Hsia (傅 書遐) に献呈した. *Rhodiola saxicola* は新種であり, *R. fushuhsiae* 同様に雌花両性花異株で, 花弁の先が鉤状の嘴状になり, 雌蕊の柱頭は膨らみ頭状となる. *Rhodiola tangutica* は旧東トルキスタンからタンゲート地方にかけて広く分布する種である.

Chamaerhodiola 節には *Rhodiola tibetica*, *R. kaschgarica*, *R. quadrifida* の3種が認められた. 最後の2種の区別はときに難しく移行形も認められる. この節の分類は今後再検討が必要である.

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